Advanced Miniature Linear Ion Trap Mass Spectrometer (LITMS) for Space Applications

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Exploration of extreme, space environments

Instrument exploring the final frontier needs to handle:

- Power/Energy/Mass Limitations
- Temperature extremes.
- Low/High pressures
- High radiation environments.
- Shock and vibrations.

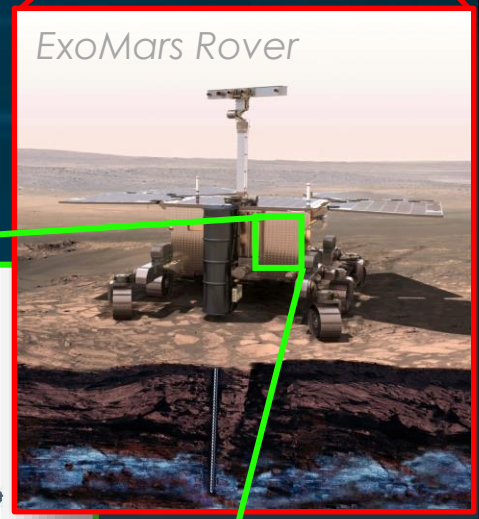
- **How did life emerge?**
- **Did life emerge elsewhere?**
- **Does life exist elsewhere?**

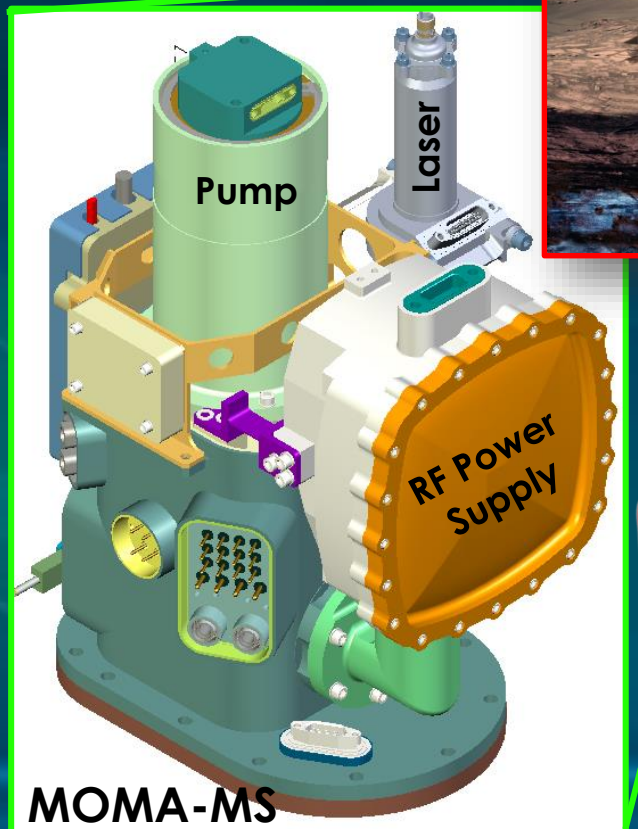
Mars Organic Molecule Analyzer (MOMA) MS on board ExoMars 2018 Rover

MOMA-MS is a **dual-source** linear ion trap MS capable of:

- Analysis of pyrolyzed and/or derivatized, gas chromatographically separated samples via **electron impact (EI)** ionization source.
- Direct sampling of crushed material at Mars ambient pressures via **laser desorption ionization (LDI)**
- Advanced analytical MS capabilities:
  - **SWIFT** filtering of selected mass range
  - **MS/MS**

(notional concept)

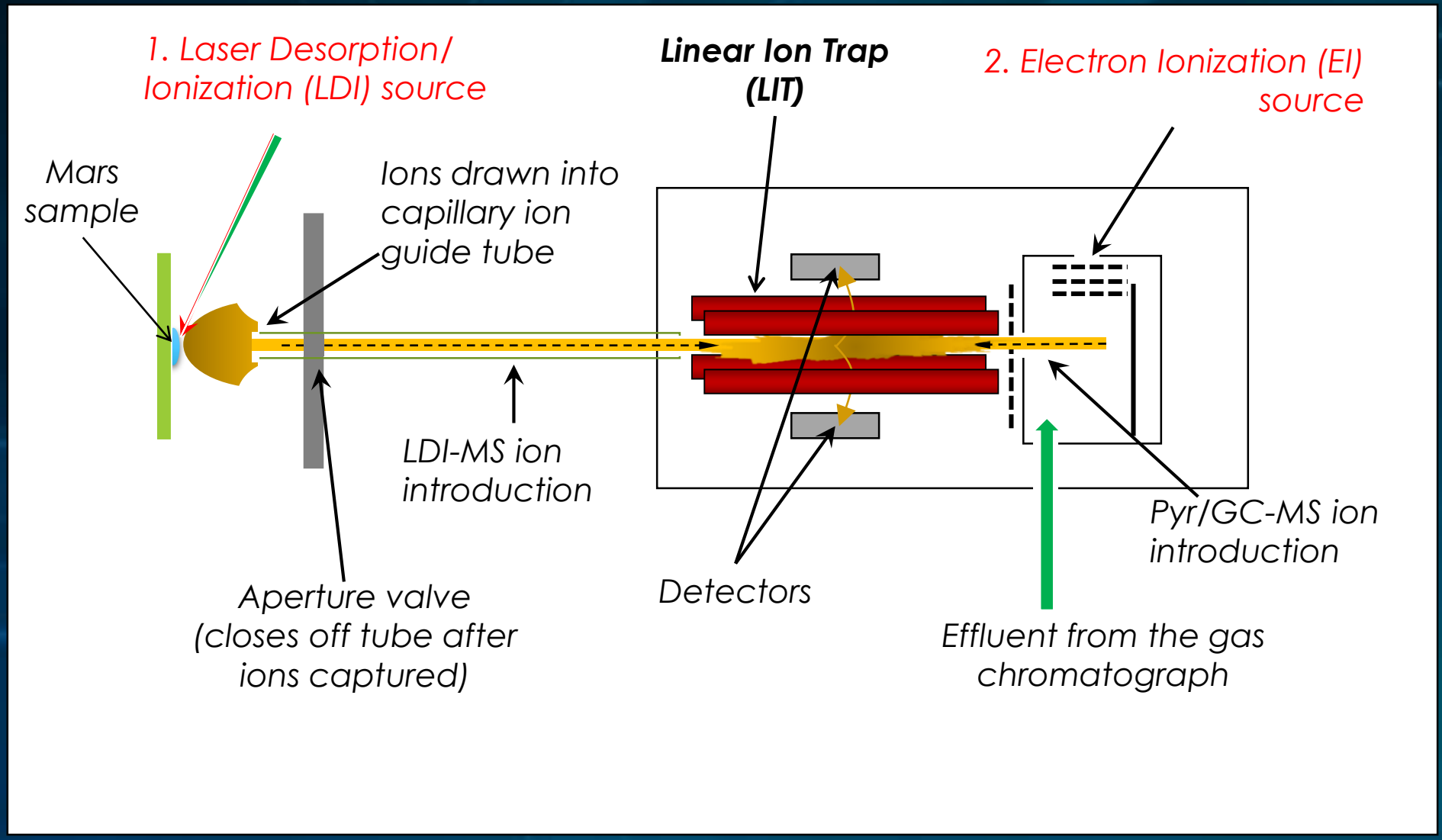




MOMA-MS

For scale

MOMA-MS Modes of Operation

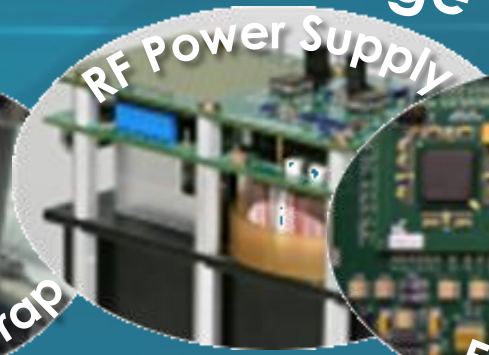


LITMS = MOMA 2.0

Linear Ion Trap Mass Spectrometer

Drill Core Sampling & Analysis

MOMA-MS Heritage



LITMS

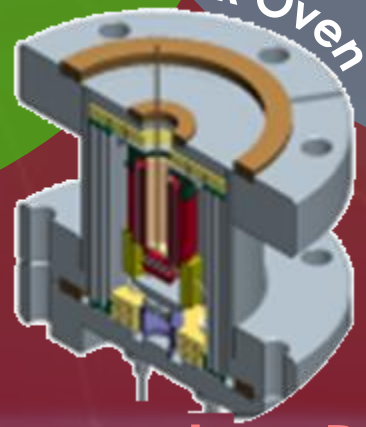
PLUS

Dual RF Supply for extended mass range:

- Low Mass Limit: **20 Da**
- High Mass Limit: **2000 Da**

Dual polarity **(+/-) Ion Detection**

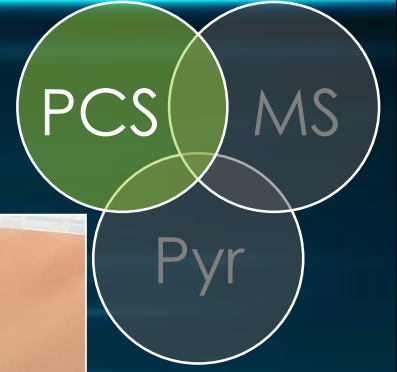
VAPoR Oven



up to 1300°C

High Temperature Pyrolysis

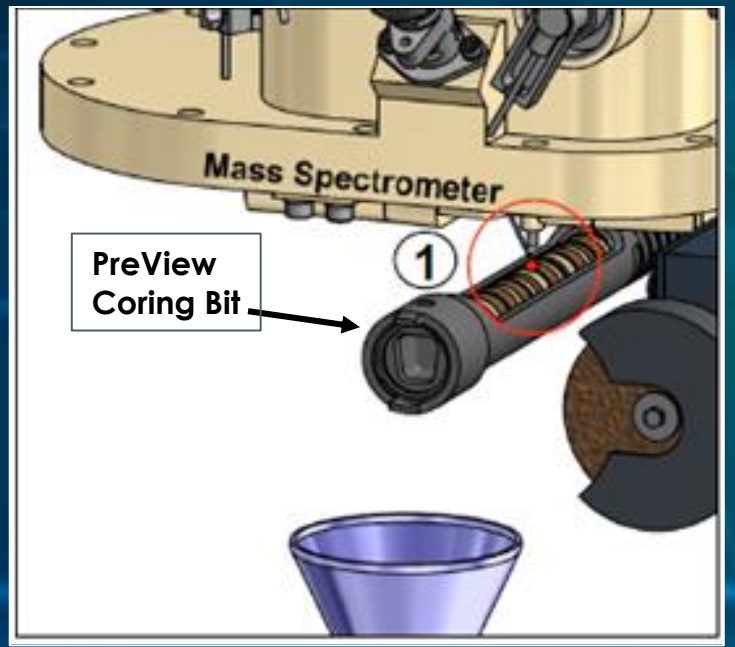
Precision Core Sampling (PCS) Subsystem

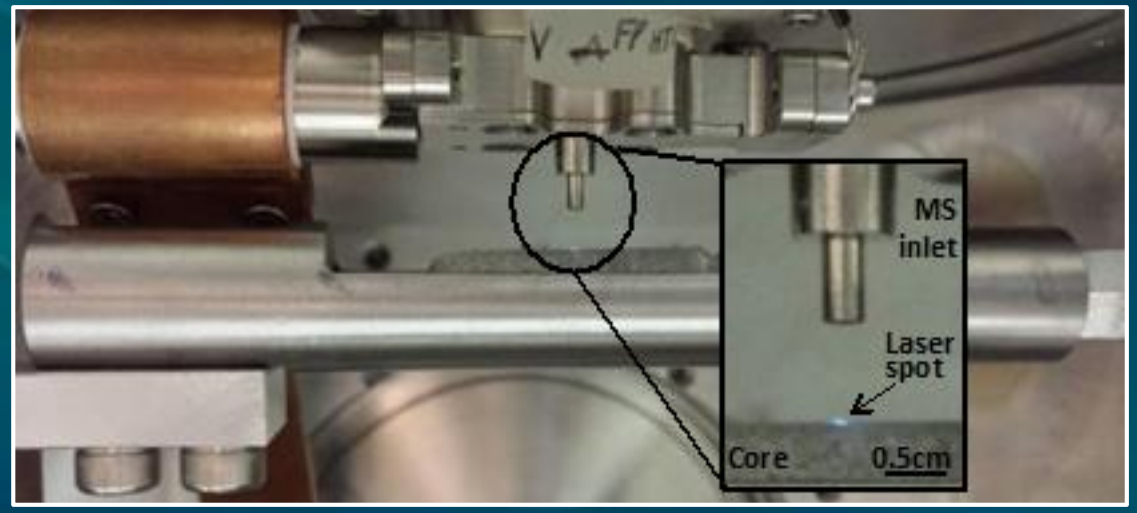


Percussive drill at the end of a 5-DOF robotic arm acquires a sample core.

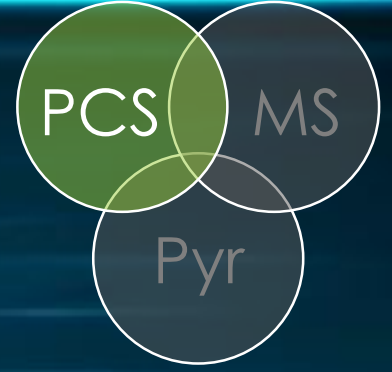
In **direct sampling mode**, the core is presented to the inlet of the MS for LDI-MS analysis.

Spatial resolution: **< 0.4 mm** (laser spot size)



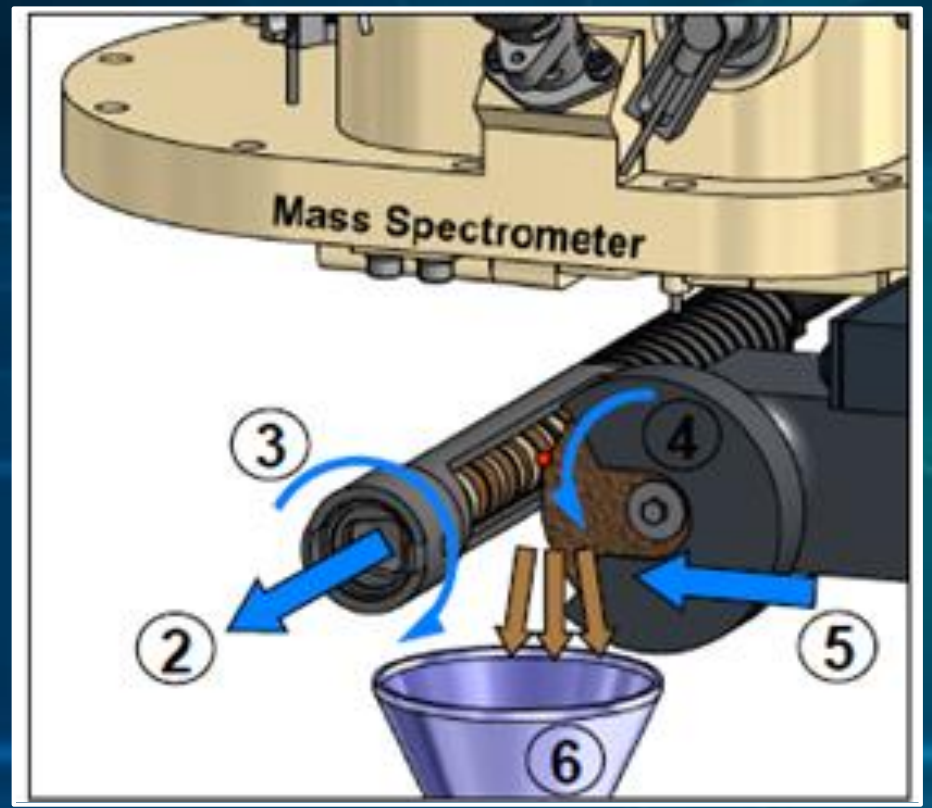


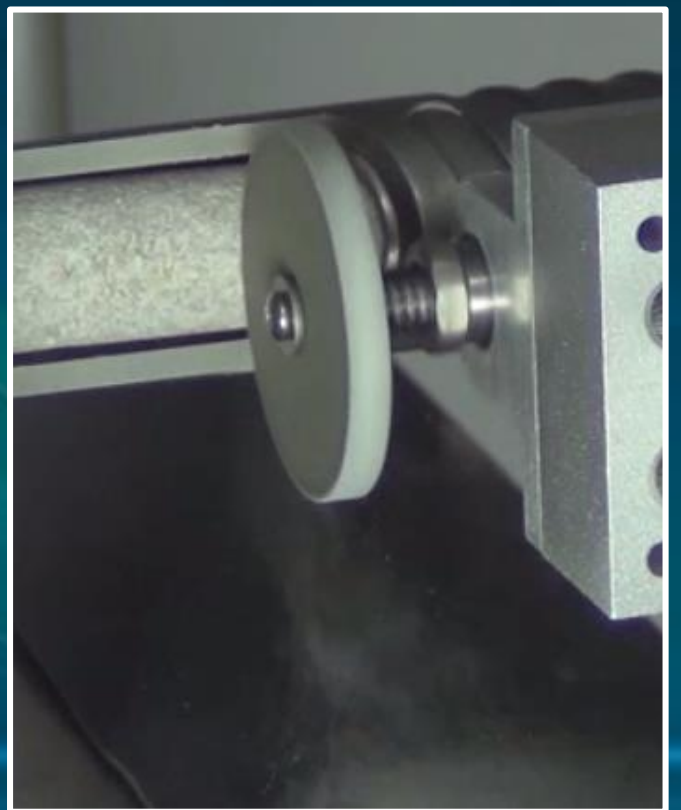
Precision Core Sampling (PCS) Subsystem



Layer of interest is sub-sampled by a grinding wheel and collected in a high-temperature oven for pyrolysis/GC analysis and evolved gas analysis (EGA)

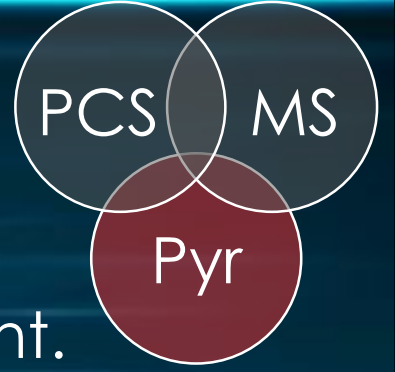
Spatial resolution: ~ **1 mm** (grinding wheel width)





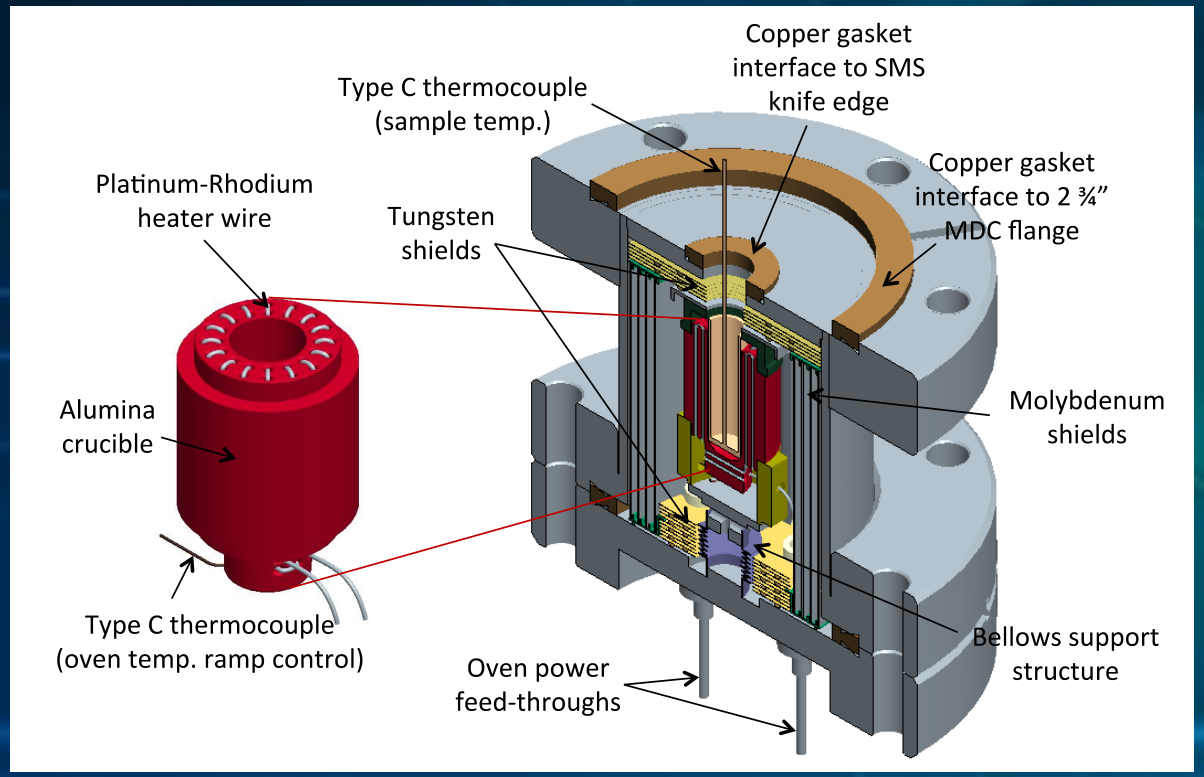
VAPoR Oven

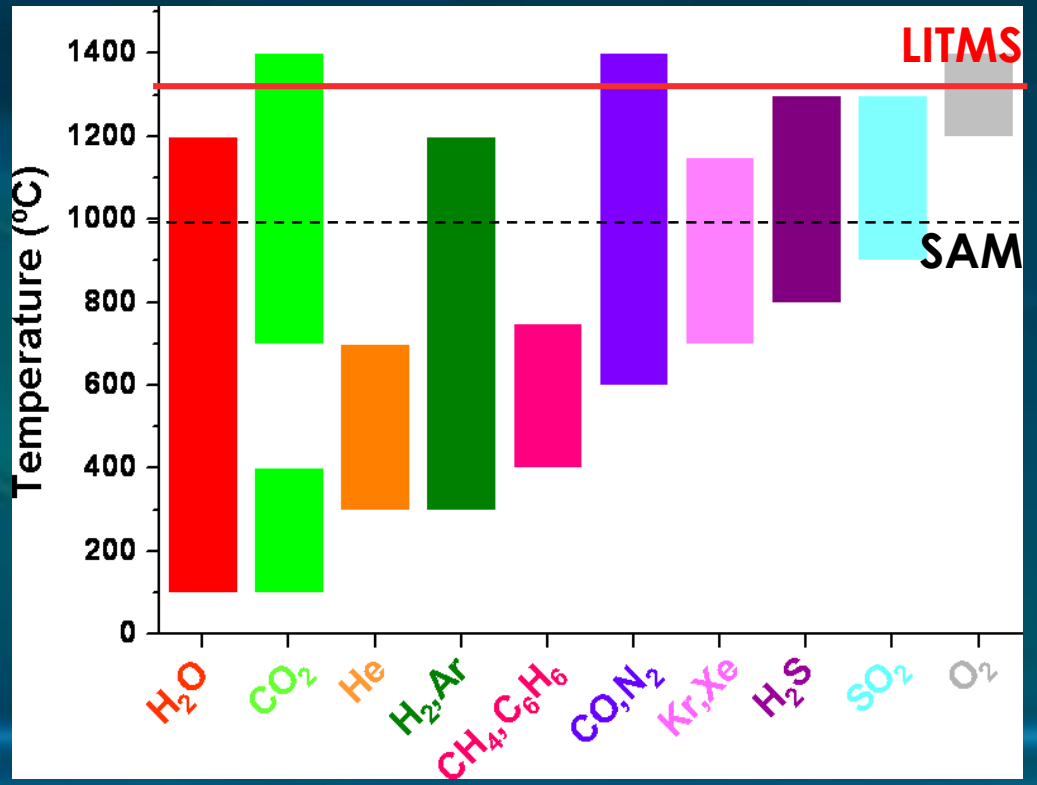
Volatile Analysis by Pyrolysis of Regolith



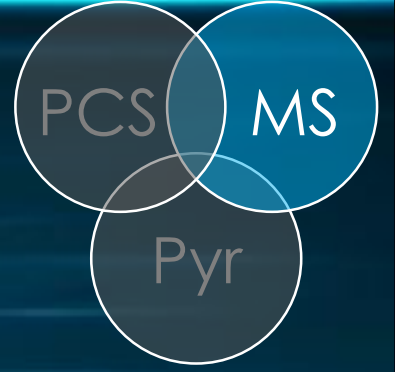
Dramatic improvement on the state-of-the-art design implemented in Surface-Analysis-at-Mars (SAM) instrument.

Demonstrated the capability to achieve **T = 1300°C** (@ 60 W) under vacuum conditions, sufficient for evolution of nearly all key volatiles in geologic samples.



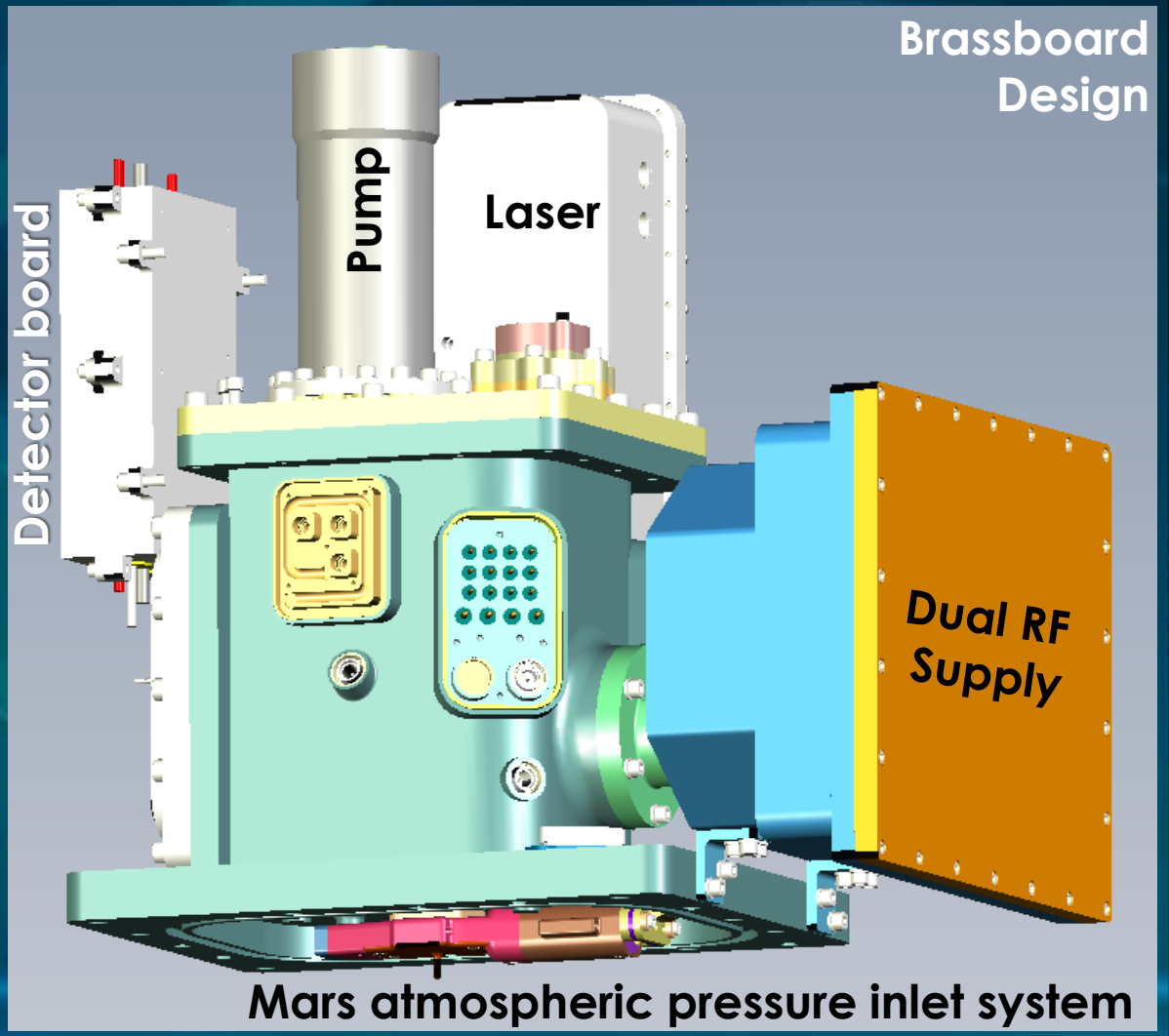


Mass Spectrometer Subsystem

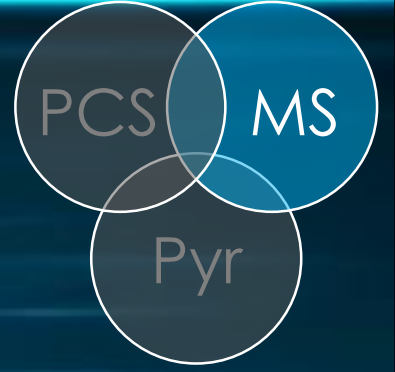


Substantial enhancement over MOMA-MS design include:

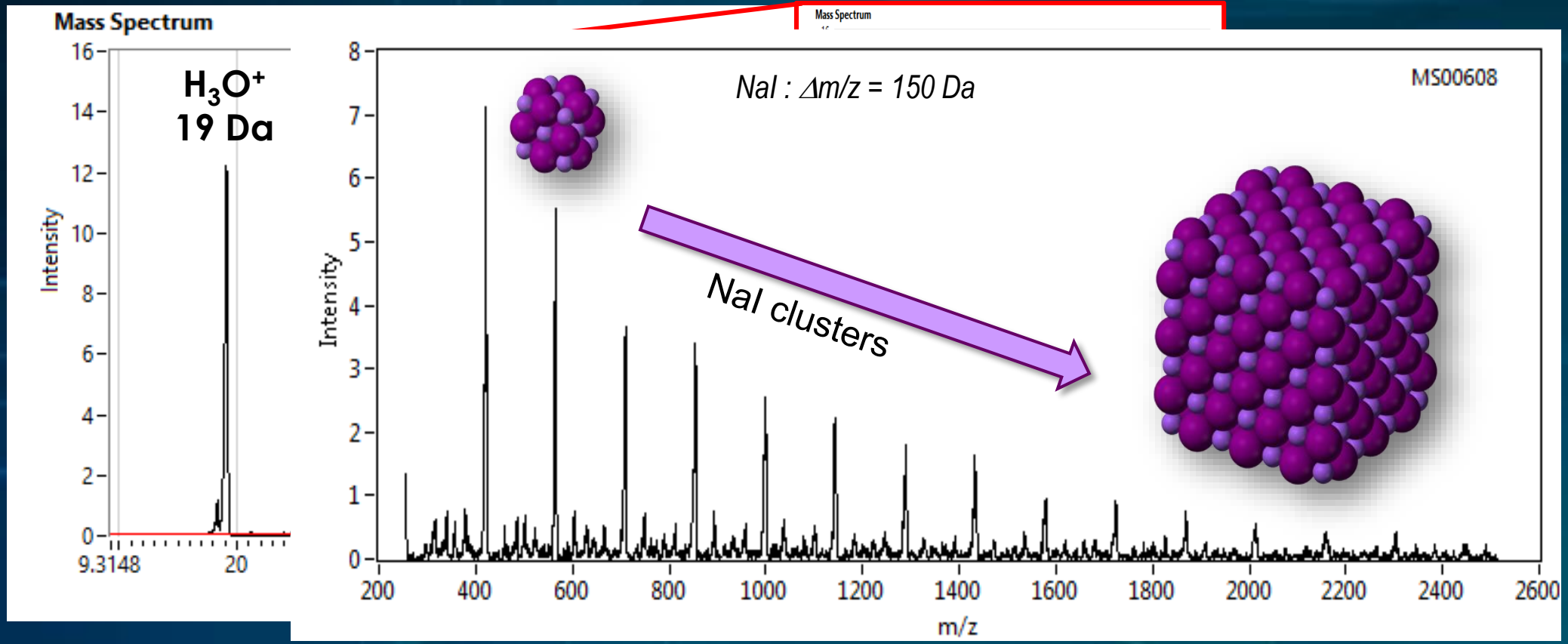
- Dual RF supply (0.7 and 1.5 MHz) for **expanded mass range** (20-2000 Da).
- Pulse-counting and analog detector electronics for **extended dynamic range**.
- Switchable polarity on all key ion trap components for **+/- ion detection capability**.
- GSFC-built 266 nm pulsed YAG laser (250 μJ/pulse) capable of 100 Hz bursts and **rapid laser energy adjustments**.



LITMS Extended Mass Range

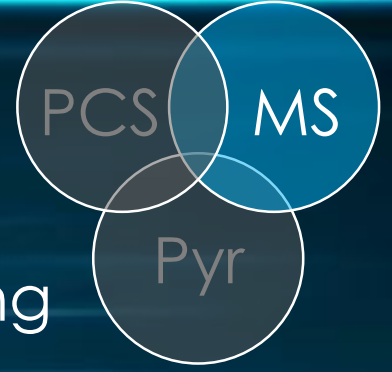


Implementation of Dual frequency RF power supplies enables 20-2000 Da mass range as demonstrated.

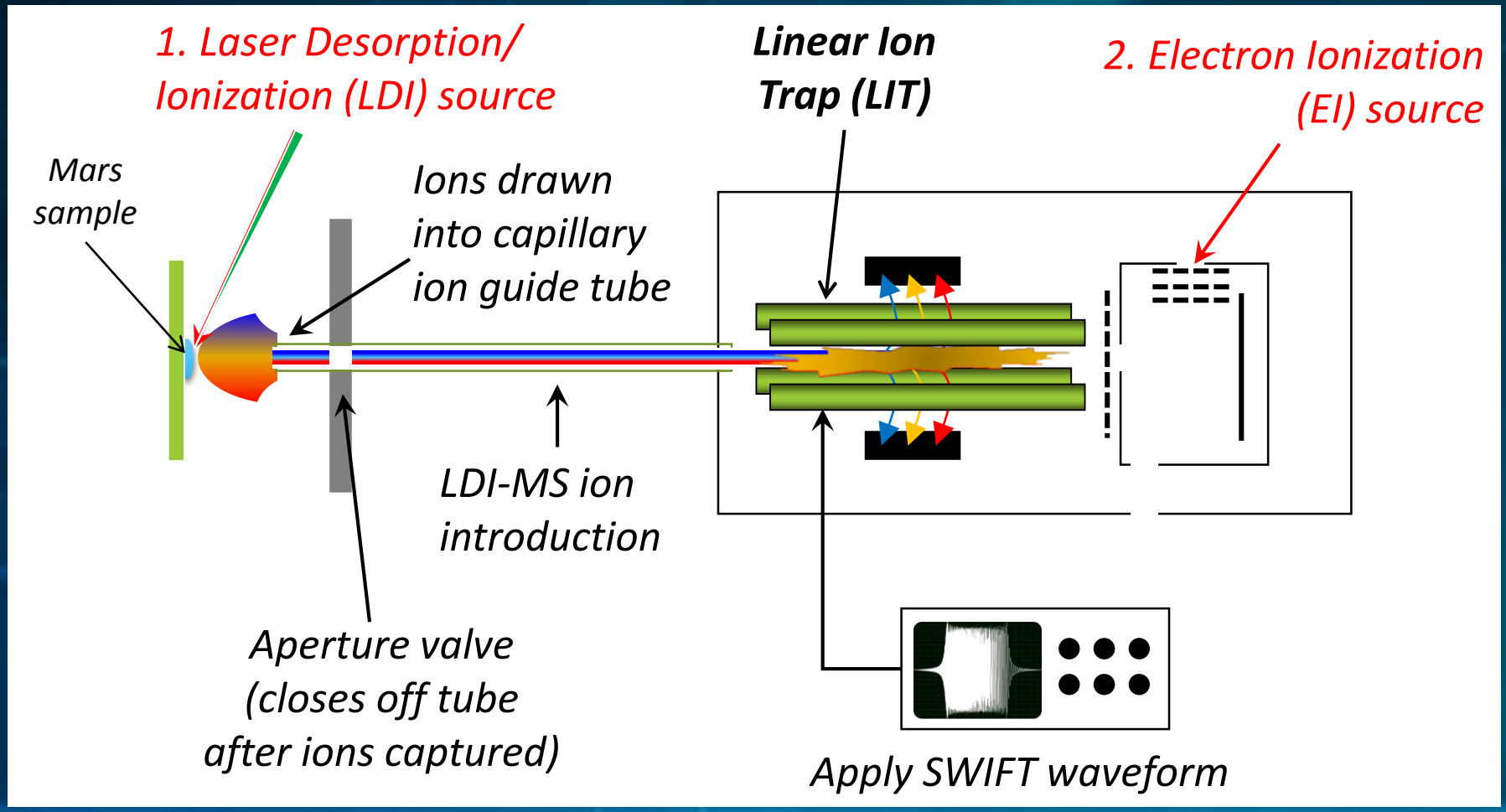


SWIFT Filtering

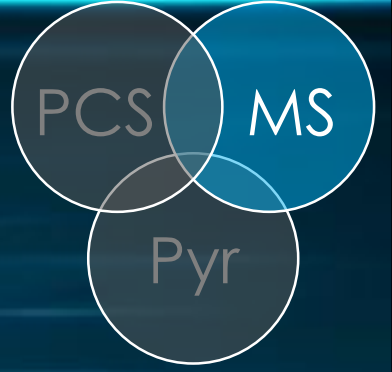
Stored Waveform Inverse Fourier Transform



Application of a SWIFT waveform to the rods during trapping will eject all but the ions within the selected mass range(s).

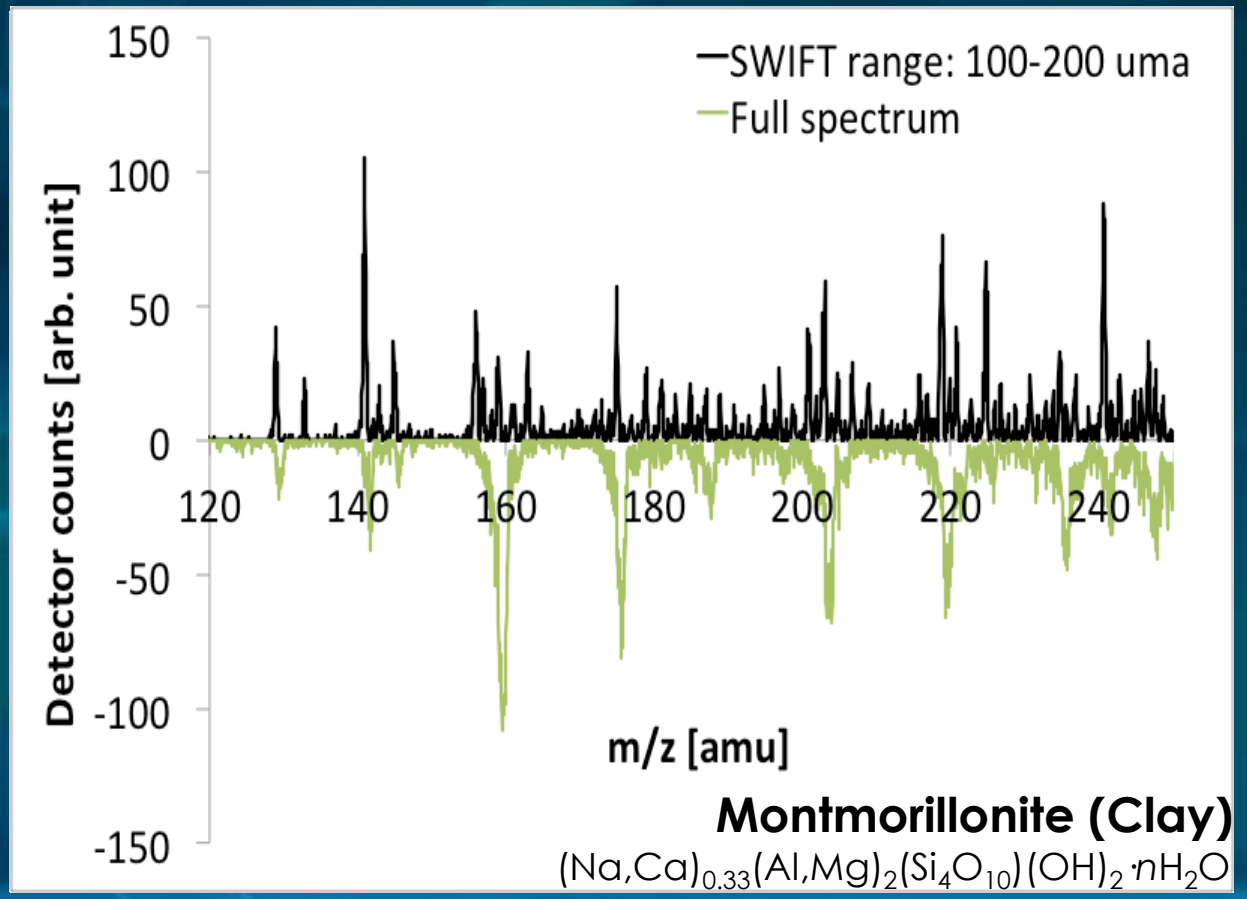


Advantages of SWIFT

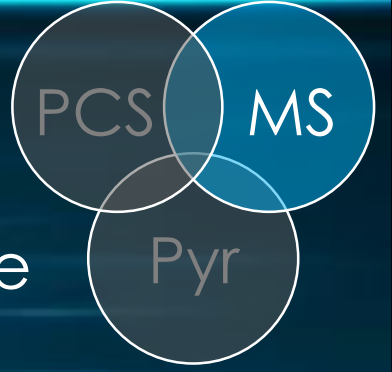


By selective trapping of ions, SWIFT enables:

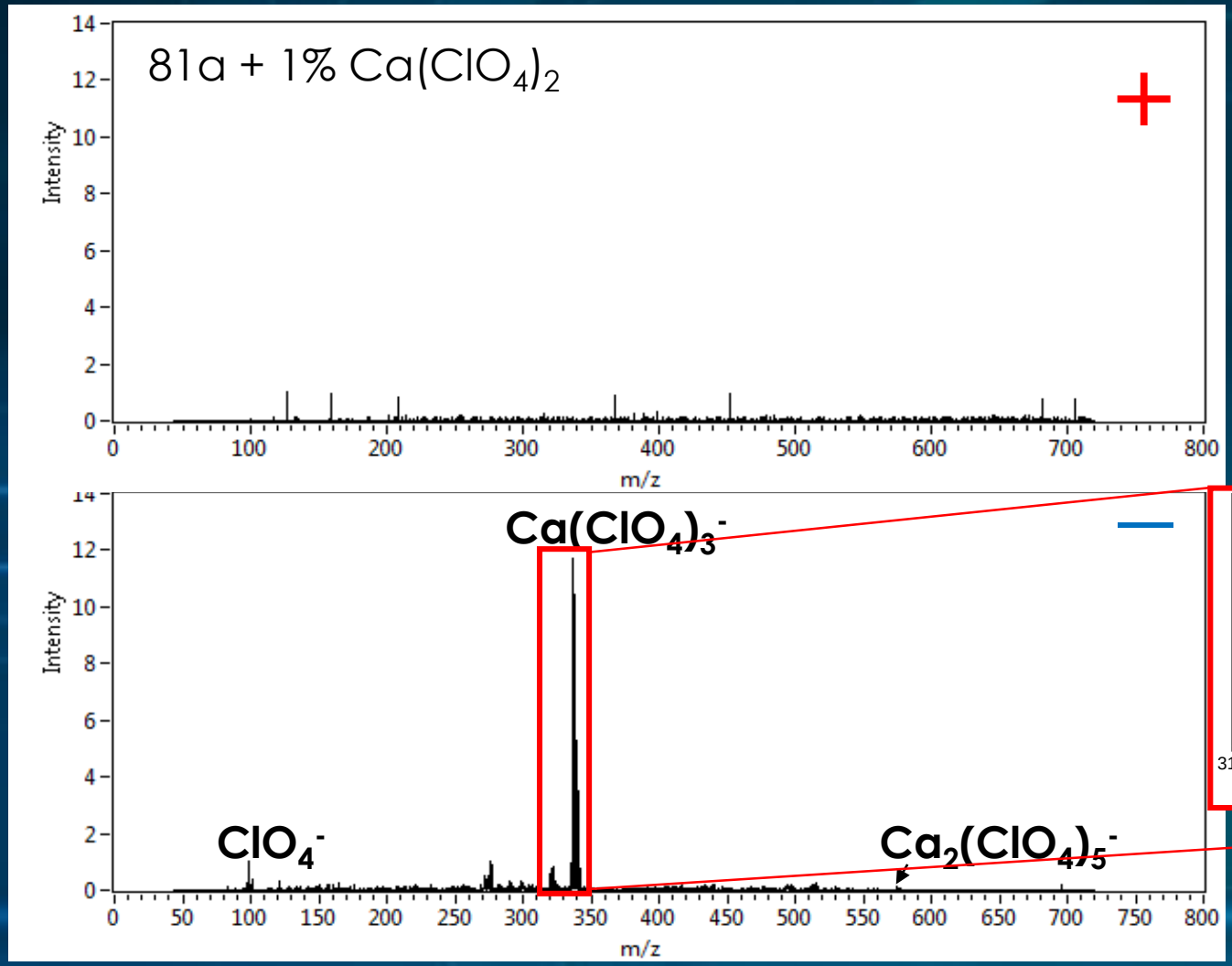
- Improved mass resolution in LDI-MS in cases of overloaded trap.
- Accumulation of ions of interest for improved detection sensitivity.
- MS/MS analysis.



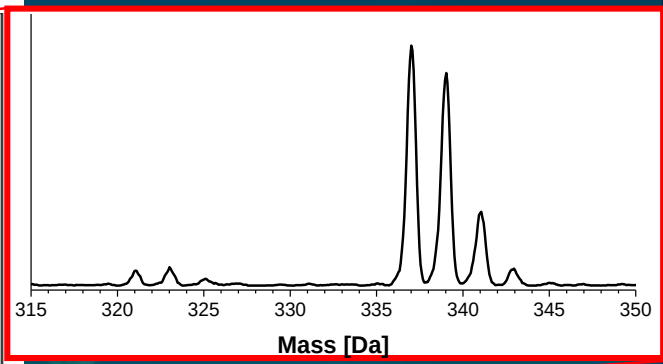
+/- Ion Detection Capability



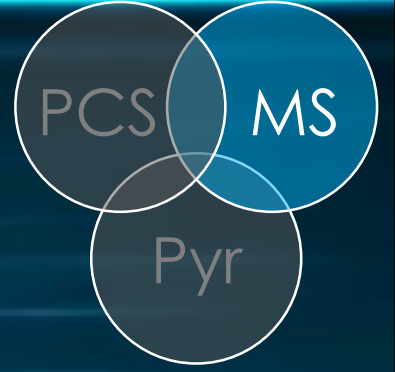
Provides complementary information on the samples since certain compounds/elements prefer to form - over + ions.



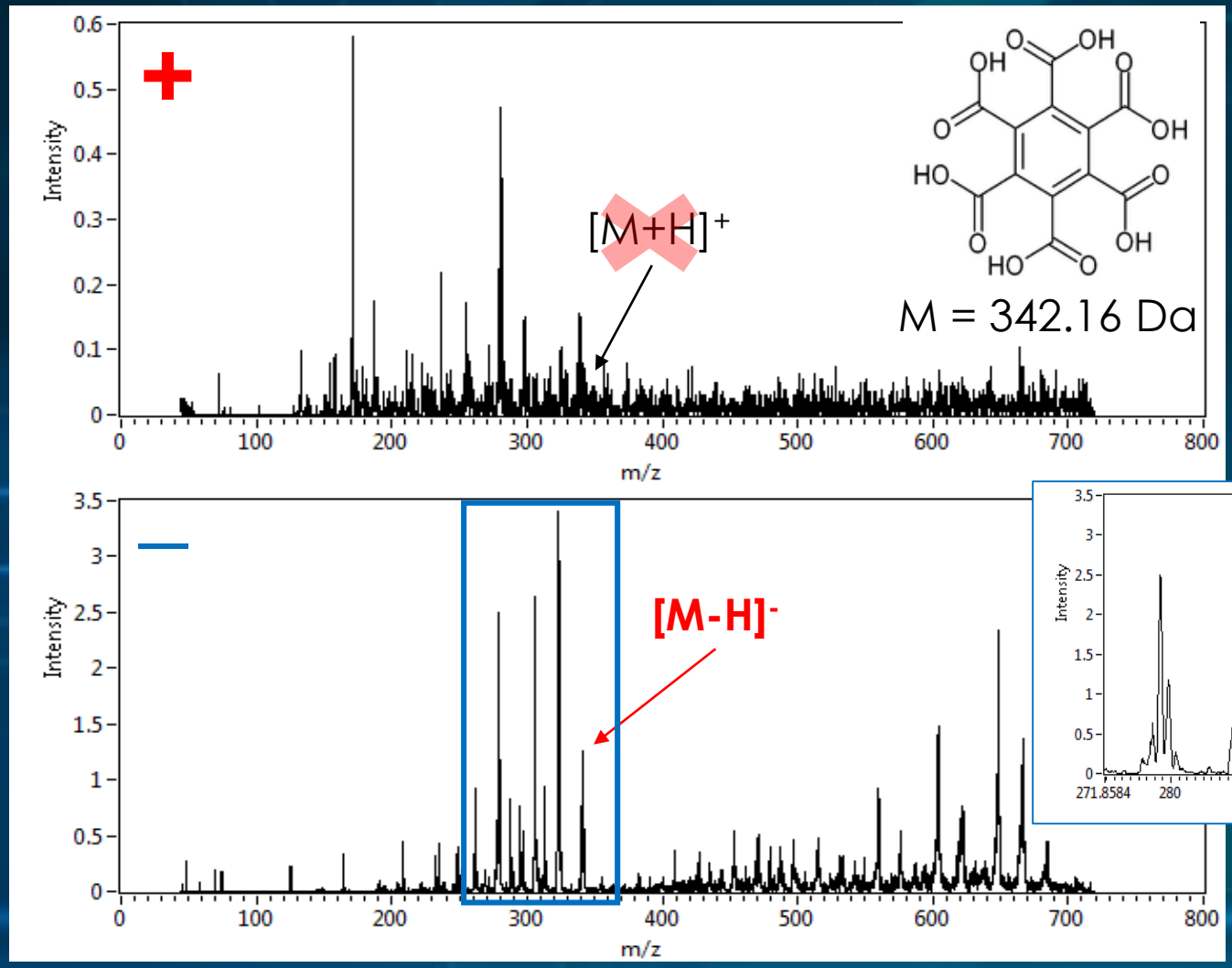
Characteristic Cl_3 isotope pattern is clearly visible

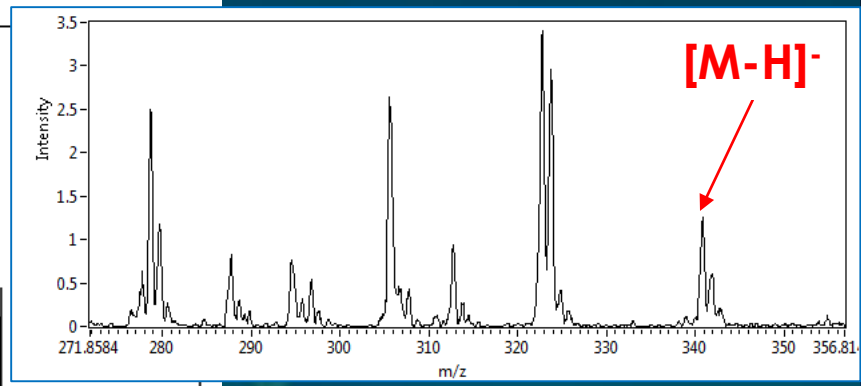


+/- Ion Detection Capability

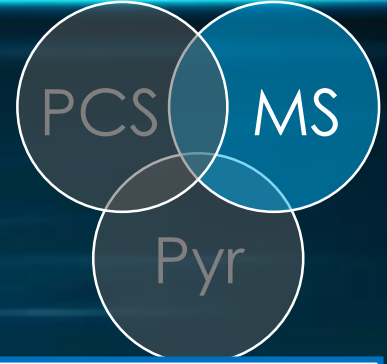


Negative ions of fragile organic molecules undergo less fragmentation, allowing identification of parent ion.

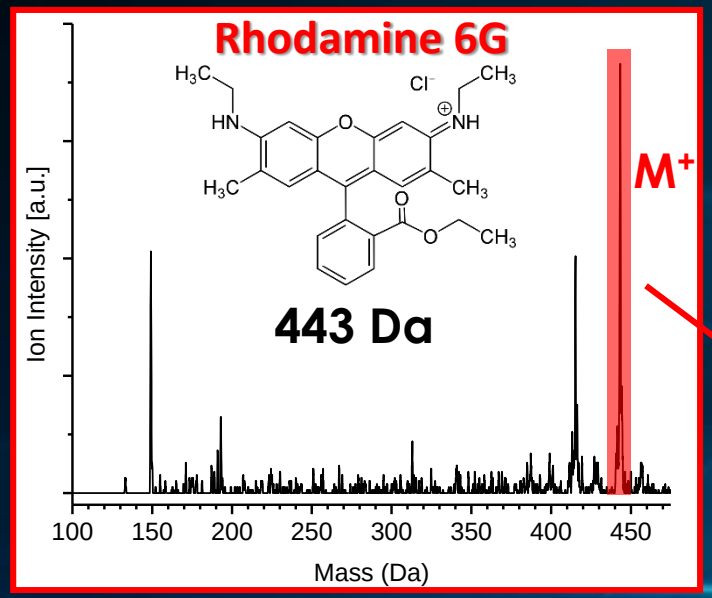


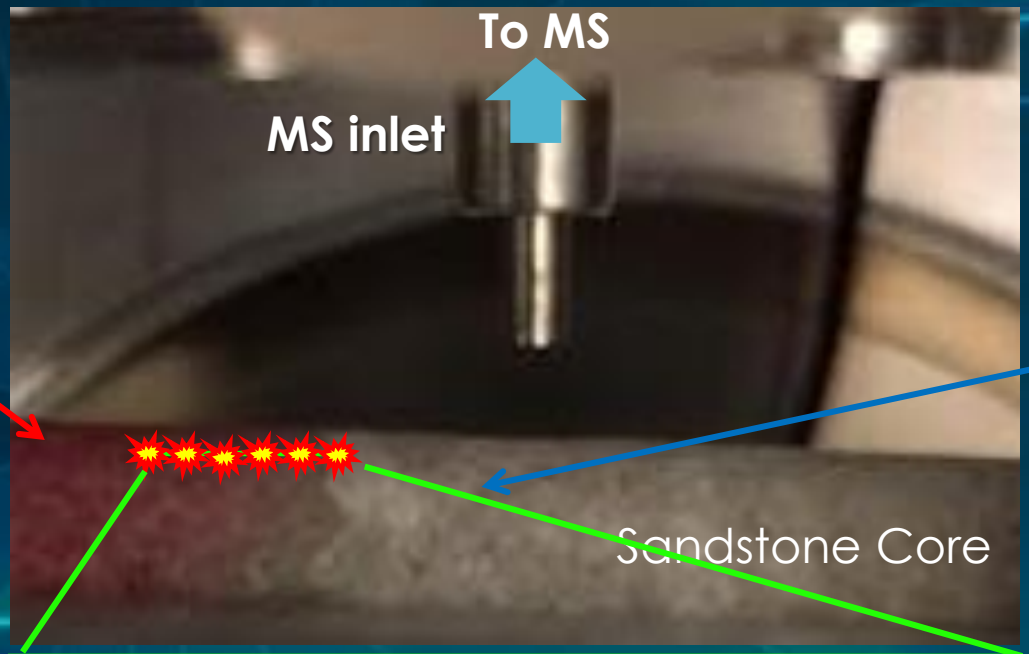


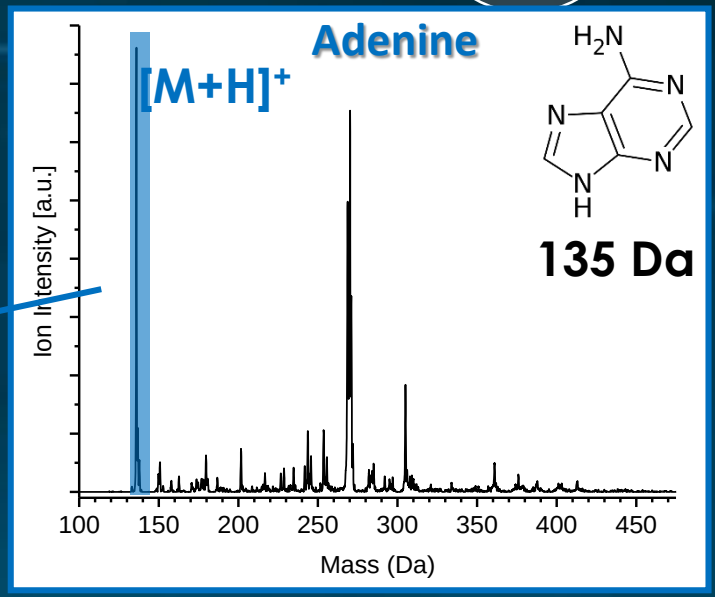
Direct LDI Analysis of Core Samples

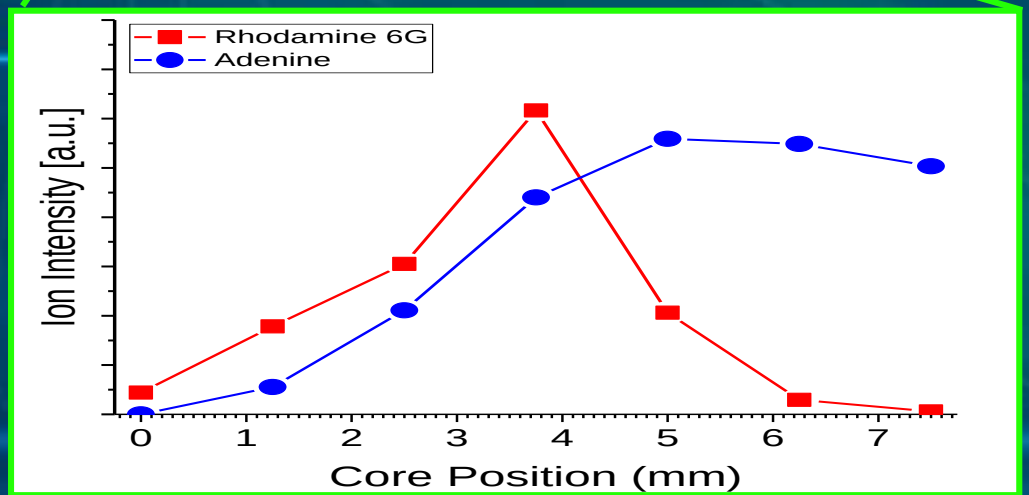


Two analyte solutions spotted on the core.









Analyte concentration gradients observed in the MS are consistent with the visual appearance of the core

Where to Next?

- **2016:** LITMS brassboard will be integrated into Mars ambient chamber and environmental tests at Honeybee for TRL6 demonstration.
- **2016-2019:** Atacama Rover Astrobiology Drilling Study (ARADS): Field test of an integrated rover drill system with Mars flight mission-ready prototype instruments.
- **2016+:** On the lookout for relevant Mission Opportunities.